The Influence of Virtual Environments on the Experience of Awe

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Abstract

Awe is a complex emotion accompanying positive benefits for well-being. There has been a notable increase in attention towards the exploration of this ambiguous emotion and its underlying concepts. Specifically, researchers have shown interest in replicating profound experiences of awe within controlled laboratory settings. It has been suggested that employing virtual reality (VR) may be a practicable method for eliciting awe, nevertheless inducing awe in a controlled experimental context remains a key challenge. In this study, a between-subject design was used including 40 participants to execute a VR study containing three different awe-inducing environments, which were a natural, space and human-made architecture (HMA) environment. The Awe Experience Scale was used as a measurement tool to capture the responses of the participants which entailed 6 subscales namely the *perception of vastness, need for accommodation, alterations in time, self-diminishment, connectedness,* and *physical sensations.* The results revealed that every environment had a significant effect on awe, whereas the natural environment was most effective, which was followed by the space environment and the HMA environment. Each environment had a distinctive method of evoking awe, with diverse impacts on the subscales of the AES. The outcomes can serve as a roadmap for designing awe-inducing environments in VR and underscore the multifaceted nature of awe which should be taken into consideration in the future.

Introduction

Within the wide range of human emotions, awe stands out as a captivating and complex experience, linking together positive emotions and wonders. Due to its complex nature, awe is sometimes equated as "feelings of intense pleasure, surprise, connectedness, and vastness but also feelings of fear and uncertainty" (van Elk et al., 2016, p.1). Awe has gained attention in research not only because of its complex nature but also because of the positive effects that accompany the experience of awe. The positive effects of awe range from an improved mood, enhanced perspective, and general increased well-being (Chen & Mongrain, 2020). Studies have found that experiencing awe daily can lead to decreasing perception of daily stress (Wang et al., 2023). In addition, the experience of awe can also contribute to other positive feelings such as compassion, gratitude, and optimism (Chen & Mongrain, 2020). In comparison, awe differs substantially from other emotions like happiness or joy because of its ambiguous and complex nature, linking together a variety of different facets which accompany this emotion (Cole, 2023).

Six Facets of Awe

As awe encompasses a complex nature, it is essential to delve into its intricate facets to grasp the varied dimensions that contribute to this profound experience. In the qualitative study of Yaden et al. (2018), the subjective awe experiences of participants were analyzed and revealed six facets that accompany the emotion of awe. The six factors that accompany and characterize the experience of awe are the *perception of vastness, need for accommodation, alterations in time, self-diminishment, connectedness,* and *physical sensations.* Out of the six facets, *perception of vastness* and *need for accommodation* yielded most attention in research because it is essential to trigger awe and its importance is undisputed. According to Keltner and Haidt (2003), perceived vastness involves encountering a stimulus that is too large for the individual to understand. For example, this could happen when an individual sees something physically large like the Taj Mahal building or Earth from space (Chen & Mongrain, 2020). The vastness in this case can also refer to something large in complexity or number (Rudd et al., 2012). The *need for accommodation* refers to the adaptation of mental frameworks in response to new information (Keltner & Haidt, 2003). More specifically, this happens when new stimuli exaggerate the conventional understanding and mental structures inhibited by an individual (Allen, 2018). Consequently, the beliefs and frame of reference of an individual must be adapted to the new stimuli to make sense of the experience, for example the view of the 828-meter-tall Burj Khalifa in Dubai has the potential to disrupt or surpass an individual's preconceived notions about the limits of human ingenuity and creative achievements (Zhang & Keltner, 2016).

The remaining facets are not explored enough yet in the experience of awe. The *alteration in time* is a facet of awe where individuals report that time moves slower whenever awe is experienced (Yaden et al., 2018). The Extended-Now Theory provides empirical support for this facet by proposing that the increased awareness of the present moment leads to the perceived expansion of time (Rudd et al., 2012). The next facet of awe is *self-diminishment* which means that whenever individuals encounter something grand their sense of self decreases and current problems or concerns lose weight in the experience of awe (Yaden et al., 2018). More specifically, individuals report that they perceive themselves smaller as than they are, on a physical and a metaphorical level (Yaden et al., 2018). Seeing awe stimuli not only leads to a shift in focus from oneself to the outside stimuli but also is linked to a feeling of *connectedness* (Chen & Mongrain, 2020). This shift in the frame of reference causes individuals to feel more connected with humanity (Allen, 2018). The last facet of awe relates to the p*hysical sensations* that accompany the experience of awe (Yaden et al., 2018). To illustrate, this includes goosebumps, chills, or the widening of the eyes. The experience of awe encompasses a variety of emotions which can be triggered.

Virtual Reality and Awe

Awe can be elicited in various situations such as watching the northern lights, seeing a sunset, or hearing about an impressive theory (Chirico et al., 2018). Nevertheless the process of replicating this complex emotion in laboratory settings to investigate awe remains a challenge. Previous studies used different methods to elicit awe for instance by sharing personal experiences either orally or written, showing awe-evoking pictures, or exposure to real awe-inducing scenarios, yet these methods entailed limitations (Chirico et al.,2017). To illustrate, sharing stories where the participant experienced awe led to the elicitation of different emotions than experienced during the real event, seeing pictures only produces low intensity of awe emotions and exposure to real scenarios is unpractical and cannot be controlled easily in studies (Chirico et al., 2017). Hence, Virtual Reality (VR) offers the opportunity to produce controlled environments for eliciting awe and has gained attention in recent research. Through VR, it has become possible to immerse into digital scenes with a feeling of presence and acquire experiences in a fashion that has not been possible before (Chirico et al., 2018). VR has made to create virtual environments that can trigger awe with the same intensity as in real life (Cebolla et al., 2019). Virtual environments (VE) are interactive spaces including different sensory stimuli like visual or auditory, with the goal of creating a realistic immersive experience for users (Quesnel & Riecke, 2018). There is a great variety of VEs which can be used in VR to elicit awe and the options to tailor and design VEs enhances the controllability and feasibility of studies.

Researchers have found that VEs differ in their effectiveness on inducing awe (Chirico et al., 2017). According to the study of Chirico et al. (2018), a landscape including a view of mountains was the most awe-inducing environment in comparison to a forest environment and a space environment. Other studies also use environments such as sunsets, opening blossoms, or parks (Rankin et al., 2019). The homogeneity of chosen environments to trigger awe in previous studies underscores the importance of investigating how different VR environments may induce awe in unique ways.

Virtual Environments

Natural Landscape Environment

A natural landscape is most frequently used in prior studies to induce awe. Studies found that nature has positive impacts on wellbeing and mood (Büssing & Baumann, 2022). In addition, the biophilia hypothesis claims that individuals have an inherent tendency to connect with nature since it contributes to stress recovery and relaxation (Chang et al., 2020). The results of one study by Chirico et al. (2018) claim that nature environments induce awe most effectively, whereas a snow mountain environment was selected as a natural environment. Nevertheless, it must be pointed out that the environments used for comparison in this study are heavily nature-related and there is a lack of variety in triggers of awe (Chirico et al., 2018). One facet that is triggered by natural landscapes is the perception of *vastness* because of the physically large characteristics of the environment (Allen, 2018). Another facet that is triggered by natural landscapes is *connection*. Studies show that individuals who are exposed to nature tend to be more prosocial and feel more connected to other individuals (Castelo & Goode, 2021). The reason for this is that experiences in nature promote self-transcendence, which is defined by individuals feeling more connected to groups or something greater than the self (Castelo & Goode, 2021).

Space Environment

Another environment important to explore is cosmic exploration, and it includes the presentation of space, galaxies, or cosmic phenomena. In contrast to aforementioned studies, the study of Quesnel and Riecke (2018) claims that the view on Earth from space is the most awe-triggering experience. The cosmic environment underlines the aspect of vastness as a trigger for awe since the physical *vastness* of space is unique and captivating (Chirico et al., 2017). In addition, the facet of the *need for accommodation* is also triggered by this environment because the view is unfamiliar and new to the individuals compared to the landscape (Yaden et al., 2018). This is also supported by the overview effect. The overview effect is the definition of the cognitive shift and intense emotions that astronauts experience when seeing Earth from space for the first time (Yaden et al., 2018). A feeling of *Self-diminishment* often accompanies the overview effect. The shift in perspective can lead to a decrease in individual concerns (Perlin et al., 2020). What also needs to be outlined is the *physical sensations* of seeing Earth from space. Goosebumps and chills have been reported by astronauts in space and participants of awe studies using the space environment (Quesnel & Riecke, 2018).

Human-made Architecture Environment (HMA)

A further environment interesting to investigate entails historical architecture which can be educational and emotionally enriching (Allen, 2018). Seeing the accomplishments of human work is another way of triggering awe in participants which has not been researched enough. The historical architecture offers an awe trigger which is not limited to natural wonders but can also arise through human ingenuity (Allen, 2018). Seeing HMA can trigger the *need for accommodation* because it challenges the perception of achievable human feats in construction and creativity, prompting a need to adapt and revise existing mental frameworks (Joye & Dewitte, 2016). Yaran (2016) described the living in urban cities containing tall buildings can be compared to perceiving art because the visual aesthetic of such cities influences the emotional reactions of individuals. While awe in nature is well-documented, HMA induced awe is underexplored and its influence is not documented thoroughly.

The present study

While previous studies have explored VR-induced awe, there is limited research investigating how different VR environments may influence the experience of awe given the complexity of the emotion. Therefore, the purpose of the present study is to examine the influence of various VR environments on awe. The aim is to find out which is the most effective environment to trigger awe. Incorporating the six facets also adds valuable data to existing literature on awe because previous research only incorporated the core features *perceived vastness* and *need for accommodation* when constructing studies (Keltner & Haidt, 2003). One will be able to emphasize how different environments influence particular dimensions of the awe experience which adds to a richer portrayal of the emotion. Hence, the research question is "What is the most effective VR environment to trigger awe?”. More specifically, hypotheses are formulated:

H1: There will be significant positive effects of post-test awe scores for every VE compared to the pre-test.

H2: The natural environment condition is expected to elicit significant positive effects in participants' awe experiences after exposure, with varied impacts on the facets.

H3: The space condition is expected to elicit significant positive effects in participants' awe experiences after exposure, with varied impacts on the facets.

H4: The human-made architecture condition is expected to elicit significant positive effects in participants' awe experiences after exposure, with varied impacts on the facets.

Methods

Study Design

To answer the research question and the hypotheses, a between-subject design was used. A between-subject design is advantageous because it eliminates fatigue effects on the participants. Moreover, a quantitative study design was used to test different environments and their effect on awe.

Participants

In sum, 40 participants were recruited for this study. Out of the 40 participants, 26 were recruited by using a convenience sampling method. The other 14 participants were recruited via SONA, the University’s Test Subject Pool System (Test Subject Pool BMS, n.d). Students from the University of Twente were given one Sona credit point as an incentive for participating in the study. The inclusion criteria were set to being over 18 and having sufficient English skills. Furthermore, the exclusion criteria contained a history of epilepsy and proneness to motion sickness. The Research was approved by the Ethics Committee BMS in the domain of

Humanities & Social Sciences from the University of Twente. Demographic information was collected from the participants including age, gender, nationality, and education. The mean age of the participants was 23 (*SD* =1.73) (see Table 1). Out of the 40 participants, 18 (45%) were female, 20 (50%) were male and 2 (5%) were non-binary. As a result of convenience sampling, 37 (92.5%) of the participants were German. Moreover, the remaining group consisted of one Dutch (2.5%), one Greek (2.5%), and one Polish American (2.5%). Referring to education, 18 (45%) of the participants were students with some university experience but no degree. This was followed by 13 (32.5%) of the participants having a completed secondary and 5(12.5%) having a university bachelor's degree. One (2.5%) participant had a completed primary, 2 (5%) had a vocational or similar and one (2.5%) had a graduate or professional degree.

Table 1

Participant Distribution

Condition	**Gender**			**Age**	
	Male	Female	Non-binary	*M*	*SD*
London	8	5	0	23.6	2.14
Mt.Everest	5	7	1	23.1	1.44
Space	7	6	1	22.4	1.45
Total	20	18	2	23.0	1.73

Materials

Awe Experience Scale

The Awe Experience Scale (AES) was used to assess the awe experience before and after the VR session (Yaden et al., 2018). To illustrate, the AES included items like “I perceived something much larger than me” or “I felt challenged to understand the experience” (see Appendix A). The questionnaire contained 30 items with 5 items per subscale which are *perception of vastness, need for accommodation, alterations in time, self-diminishment,* *connectedness,* and *physical sensations*. The answer possibilities range from 1 which is "strongly disagree" to 7 which is "strongly agree". The alpha coefficient of the AES equals .93 which shows that the items of the AES measured the experience of awe with a high degree of reliability. The internal consistency for each factor was strong with an alpha of .80, which indicates a good reliability (Yaden et al., 2018).

Hardware

For the execution of the experiment, a room in the BMS lab of the University of Twente was reserved for the period of data collection, which is a room specialized for experiments with VR equipment. The room entailed a desk with a computer, a screen, and a chair. Moreover, the VR equipment Oculus Rift S was used for the VR experiment. It included VR glasses and two controllers.

Software

With the Oculus program access to the VR environments was enabled. The environments were chosen via the Google Earth application. More specifically, the environments of London, Mount Everest, and Space were selected. The London environment enabled participants to view London from above, including Big Ben and surrounding architecture and streets (see Figure 1). The Mount Everest environment included the view of Mount Everest and surrounding mountains building a mountain landscape (see Figure 2). The last environment contained the view of Earth from outer space with stars and a galaxy surrounding it (see Figure 3). All the environments entailed the possibility of flying around using controllers to explore the environment. Furthermore, the participants could drag the sun in a preferred direction, creating sunsets, sunrises, or a night sky.

All the data was collected and saved by the Qualtrics platform which is a safe online data collection program (Qualtrics XM, n.d). Qualtrics enables the management of a large amount of data by summarizing, making trends, data analysis, and reporting the data. It is a user-friendly program which also allows for sharing projects and editing together (Qualtrics XM, n.d)

Figure 1

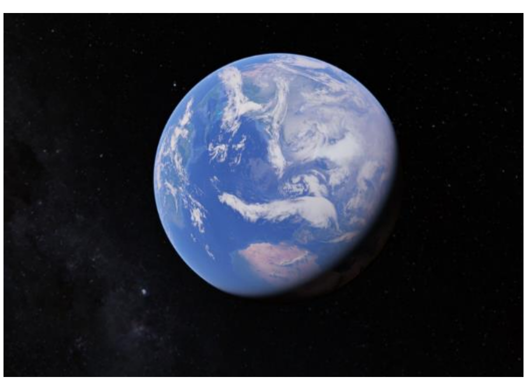
London VE

Figure 2

Mount Everest VE

Figure 3

Space VE



Procedure

The participants either signed up over Sona or were invited to participate in the study. The experiment started by telling the participants to sit down and follow the instructions written on the screen. First, the informed consent was shown, including risks and other information about the study (see Appendix B). Then, the demographic questionnaire appeared on the screen which had to be filled out. Next, the participants were instructed over the screen to be aware and perceive the current situation for a moment in order to have a neutral reference situation for the first AES questionnaire. The participant could decide alone when to continue by pressing on the arrow which leads to the next screen. The participants had to fill out the AES on the computer and they were instructed to give their answers based on the neutral reference situation. When the participants were done with filling out the AES, they were informed verbally that the experiment now comes to the VR experiment part and about the possibility of always quitting the study when the use of the equipment leads to negative consequences for example dizziness or nausea. The VR experiment was prepared by the researcher by selecting the environment on the Google Earth program. To have an equally distributed set of data, it was tried to have the same number of participants for each environment. To achieve this, each day was determined for one condition. After the VR environment was selected, the participants were given a short verbal introduction to the correct use and adaption of the equipment. When the equipment was put on and there were no more questions or uncertainties from the participants, they were given a time limit of 5 minutes to explore the given environment. In the meanwhile, the time was tracked by the researcher and if there were technical questions the researcher was present for support. After 3 minutes the participants were told to search for a point in the environment and to rest for 2 minutes, to collect the impressions of the environment in depth. After the time limit of 5 minutes was over, the AES was filled out a second time on the computer, where the participants answered the questionnaire based on the experiences collected during the VR session. After filling out the AES for the second time the experiment was completed.

Data Analysis

All the data was analyzed using R Studio. Beforehand, the dataset was screened, and missing data was excluded from the dataset. For the descriptives, the mean scores and corresponding standard deviations were calculated for the demographic variables gender, age, and education.

For the inferential statistics, a check for normality was executed first to get an overview of the distribution of the data. For this, the Shapiro test and boxplots for visualization were used for every condition. The outcomes of the Shapiro test showed that the data was not normally distributed (see Appendix C), therefore parametric data analysis methods were replaced by non-parametric methods. For checking for significant effects, the Wilcoxon signed-rank test was used as a non-parametric equivalent. This was used on pre and post-scores of every facet in each condition. When the results showed a significant effect, the effect size between the pre and post-means was calculated by using Cohen's d. The d-estimate revealed insight into the effect size, whereas a d-estimate of around 0.2 indicates a small effect, 0.5 a medium effect, and a d-estimate of above 0.8 is considered to have a large effect (Rice & Harris, 2005).

Results

Descriptive Statistics

The outcomes of the descriptive statistic reveal that all of the environments showed higher awe mean scores after exposure to the VR environments than before. The natural environment had the greatest increase with a pre-exposure mean of 2.48 and a mean of 5.33 after exposure (see Table 2). This is followed by the space environment with a pre-exposure mean of 2.98 and a post-exposure mean of 4.95 (see Table 2). The HMA environment had the smallest increase with a pre-exposure mean of 2.88 and a mean of 4.74 after exposure (see Table 2).

Inferential Statistics

Hypothesis 1 Environments and Awe

The Wilcoxon signed-rank test showed that all environments have a significant positive effect on post-scores (see Table 2). Therefore, hypothesis 1 is accepted.

Table 2

Results facets

Facet	Condition	Scores				Cohens d	Wilcoxon	
		M Pre	*SD* Pre	*M* Post	*SD* Post	*d* estimate	*V*	*p*
Alteration in Time	HMA	3.63	1.35	5.49	0.74	1.70	91	0.001
	N	3.03	1.38	5.60	0.73	2.32	89	0.002
	S	3.73	1.51	4.84	0.74	0.93	81	0.07
Self-diminishment	HMA	2.77	1.06	5.10	1.25	2.01	89	0.002
	N	2.91	1.42	5.84	0.76	2.56	78	0.002
	S	2.64	0.82	4.98	1.22	2.24	78	0.002
Connectedness	HMA	2.66	0.78	4.20	0.93	1.79	90	0.002
	N	2.38	1.05	5.03	0.64	3.02	91	0.002
	S	3.16	1.42	4.47	1.11	1.02	76.5	0.03
Vastness	HMA	2.80	1.15	4.73	1.42	1.79	90	0.002
	N	2.15	0.84	6.04	0.75	4.87	91	0.001
	S	2.97	1.25	5.90	0.64	2.93	103.5	0.001
Physical Sensation	HMA	2.15	0.56	4.61	1.08	2.85	90	0.002
	N	1.89	1.09	4.66	1.50	2.10	78	0.002
	S	2.74	1.14	4.60	1.27	1.53	101	0.002
Need for accommodation	HMA	3.29	1.30	4.33	1.00	0.89	66	0.03
	N	2.51	1.02	4.83	1.01	2.27	88	0.003
	S	2.63	1.19	4.94	0.93	2.15	101.5	0.002
Awe	HMA	2.88	0.79	4.74	0.68	2.51	91	0.001
	N	2.48	0.92	5.33	0.66	3.53	91	0.0002
	S	2.98	1.03	4.95	0.40	2.52	104	0.0002

Note. The conditions were shortened to N= Natural environment and S=Space environment.

Hypothesis 2 Natural Environment and Awe

In the natural environment condition, all facets had significant positive effects after completing the Wilcoxon rank test (see Table 2). Cohens d revealed that after the VR exposure, the score for vastness in the natural landscape condition increased and had the largest effect (see Table 2). This facet had the largest increase among all facets and environments. The facet connection had the second largest increase, and the effect was large (> 0.8) considering Cohens d (see Table 2). The least effect yielded the facet *physical sensation* (see Table 2). Because the natural environment showed a significant effect and there were different impacts on the facets, the hypothesis can be accepted.

Hypothesis 3 Space Environment and Awe

For the space condition, all the facets had significant effects, except for the facet alteration time (see Table 2). Regarding effect sizes, the space environment had the greatest influence on the facet vastness (see Table 2). This was followed by the facet of self-diminishment and the facet that was influenced least in this environment was alteration in time (see Table 2). Since the space environment had a varied effect on the different facets of awe, hypothesis H3 is accepted.

Hypothesis 4 HMA and Awe

Referring to the last hypothesis, all of the facets had significant positive effects. The HMA environment had the largest effect on the facet *physical sensations*, which is followed by the facet *self-diminishment* (see Table 2). The facet *need for accommodation* in HMA yielded a significant positive result, but had the smallest increase out of all facets (see Table 2). Hence, hypothesis 4 is accepted.

Discussion

VEs Influence on Awe

This study aimed to find out the most effective VR environment to influence awe and its subsequent facets. Generally, all environments triggered awe and therefore are suitable to use.

Nevertheless, one can say that the natural landscape showed the biggest effect on the perception of awe, which was followed by the space environment and HMA environment. This outcome is not surprising looking at the amount of research covering the natural environment. As already stated in the introduction there are several reasons why this environment is the most awe-inducing. For example, because of the biophilia hypothesis which states that individuals have an inherent tendency to connect with nature which has relaxing effects (Chang et al., 2020). In addition, the physical features of the environment are rich in detail and fascinating which influences positive emotions and awe (Ballew & Omoto, 2018). Even though every environment triggered awe, it must be emphasized that the environments varied in their influence on the different facets of awe and addressed different aspects.

Natural Environment and Awe Facets

Since this environment is the one revealed to be most effective, the question arises what makes this environment responsible for the high awe perceptions in participants. Vastness is the facet most triggered in this environment and it seems to be no coincidence that the most influential facet in this environment is also one of the core features of awe invented by Keltner and Haidt (2003). The role of vastness seems to be essential in the perception of awe which is also in line with the outcomes of several studies which claim that the physical large characteristics of a natural environment are responsible for heightened emotional responses and transcendental experiences in individuals (Allen 2018, Ballew & Omoto, 2018, Rauhoeft et al., 2015). Out of all-natural landscapes, the mountain landscape has been shown to trigger the facet vastness most intensively as found out in the study of Rauhoeft et al (2015). A possible reason for this might be the lack of human-made boundaries which enhance the perception of unbound vastness in natural environments (Rauhoeft et al., 2015). This is also supported by this study because the natural environment had an outstandingly large effect on the facet vastness, indicating a physically vast environment, with the highest post-measurement results out of all facets in all environments. Apart from the facet vastness, there is ample evidence that exposure to nature leads to a feeling of connection to other individuals, even to individuals who are not socially close (Castelo & Goode, 2021). This can also be seen in the results because connection had the second highest effect in the natural environment. The natures' awe-inspiring properties can lead to a heightened focus on other individuals, elevated prosocial tendencies, and a greater willingness to show concern and offer assistance to others (Goldy & Piff, 2020).

Surprising outcomes were referring to the fact that the facet physical sensation was triggered least in this environment. The fact that *physical sensation* had the lowest results in the natural environment is contradictory to the findings of Quesnel and Riecke (2018) who found out that the higher the ratings of awe, the higher the occurrence of goosebumps. Since the natural environment had the highest ratings for awe and the lowest result for physical sensation, this is a contradiction. Reasons for this must be closely examined, and when following the ideas of Quesnel and Riecke (2018) one possible reason can be the fact that the interactivity using controllers can impede the experience of physical sensation. The use of controllers can be distracting for the participants, so they are more focused on the operation of the controllers instead of being open to the experience of awe.

Space Environment and Awe Facets

Continuing, the space condition was revealed to have the greatest effects on the facet's vastness and self-diminishment, whereas the facet alteration in time had no significant effect. The fact that the space condition is the second to have the highest scores for the facet vastness again underlines its importance in the experience of awe. This revelation is in line with the findings of Rudd et al (2012) which claim that the view on earth is so unique to individuals that the experience of vastness is captivating. Furthermore, the theory that the overview effect when observing Earth from space influences self-diminishment because it can decrease individual concerns, is also supported by the results (Perlin et al., 2020). Stepanova et al. (2019) revealed that the overview effect also is responsible for a transcendent experience that leads to a feeling of connection with all living beings and the planet. The facet alteration in time is the only facet that had no significant effect in this environment. A reason for this could be that the participants could not explore much in this environment and were more in a static state, which could have influenced their perception of time (Chirico et al., 2018). Participants could fly around as in the other environments, nevertheless there was nothing to explore in the universe apart from the view on earth and blackness around it, leading the participants to only observe the earth.

HMA Environment and Awe Facets

The facet *need for accommodation* surprisingly had the weakest effect in this environment. This is a contradictory finding looking at the characteristics of the environment because the HMA environment differs substantially in its spatial properties in comparison to the other environments. To illustrate, London is a city with diverse architecture and dynamic urban scenes which makes it a sensory-rich environment (Punter, 2011) The given characteristics of the environment underlie the basic concept of the facet *need for accommodation,* which is the restructuring of mental schemas when perceiving novel stimuli, and thus should have an influence on the individual (Allen, 2018). Familiarity factors could have influenced the results because the stimuli have to be novel or unfamiliar to challenge existing mental schemas according to the definition of the facet needed for accommodation. Compared to seeing Earth from space or being on the highest mountain on Earth, London might have already been familiar to the participants either through real-life experiences or general knowledge and thus did not offer sufficient challenging elements. The question arises whether the same results would have been achieved if the sample's nationality demographics were more varied.

Surprisingly, the HMA environment had the greatest effect on the *facet physical sensations*. This is an unexpected finding considering that there are not many previous reports in the literature describing this effect, and also because human-made architecture has not been included in previous studies to induce awe. Joye and Dewitte (2016) tried to fill this research gap by focusing on the psychological effects on individuals when exposed to overwhelmingly tall buildings. The outcomes of this study claim that high buildings are effective in triggering awe and are directly linked to the physical sensation of being in a “freezing” state. In other words, the freezing state is also called behavioral immobility and refers to a tense body posture and stiffness of muscles (Joye & Dewitte, 2016). Interestingly this knowledge about the paralysis-inducing characteristics of buildings has been exploited in the past by the Nazi regime who purposely designed overwhelmingly tall buildings to induce this freezing state and feelings of smallness to maintain power and weaken the general population (Joye & Dewitte, 2016). This feeling of smallness when exposed to tall buildings reported in the study of Joye & Dwitte (2016) also is in line with the findings of this study because self-diminishment had the second largest effects after the physical sensations facet.

Literature offers not much methodology for the effect of physical sensations in this environment, but it resonates with the broader literature on awe-triggered responses, particularly goosebumps. After cold reactions, awe was found to be the second most frequent cause of goosebumps (Schurz et al., 2012). Moreover, there was a noteworthy pattern within the awe-elicited goosebump reactions which indicated that nearly half of the awe-inducing stimuli were social. To illustrate, 46.1% of the awe-inducing stimuli that were responsible for goosebumps reactions were social stimuli that resulted directly from admiring the qualities, deeds, or performance of other individuals (Schurz et al.,2012). Relating this to the outcomes in this study, it has to be emphasized that seeing the intricacies of human-made structures, streets, and various architectural elements, the HMA environment could fall under the social categorization of awe trigger. The existing literature claims that monumental architecture triggers the physical sensation of the individual (Joye & Dwitte, Schurz et al., 2012). Awe experiences induced by human-made architecture have a significant link to the manifestation of goosebumps and behavioral immobility. This finding not only expands our understanding of awe but also underscores the intricate interplay between environmental stimuli, emotional experiences, and the physical manifestations of awe-related sensations.

Practical Implications

Concluding it can be outlined that awe can be triggered effectively in VR in different environments, with the natural environment having the greatest effect. When designing a study, the results can add unique nuance to accentuate in what direction the research should go. For example, if researchers are especially interested in exploring the self-diminishing and transcendent effects of awe, they should consider choosing a space environment because it has high effects on the facet of self-diminishment. Another example could be that when the dependent variable set up in a study is a connection, it is advisable to choose a natural environment hence it had a high effect on this facet. When researchers aim to explore the physical reactions from the body to the awe experience, choosing an HMA environment is beneficial. It has to be emphasized that awe is a complex emotion, accompanying many different ambiguous emotions and eliciting awe could go in different directions. The outcomes of this study offer a roadmap for future studies, guiding researchers into the design of specific elements that contribute to awe-inspiring virtual experiences.

Strengths and Limitations

Strengths

This study has several noteworthy strengths that together support the methodological reliability and comprehensiveness of its conclusions. Since the majority of studies are making use of only natural environments to trigger awe, one strength is the inclusion of three different environments. A thorough investigation of awe experiences is made possible by the purposeful diversity in environmental triggers, which captures the complex reactions evoked by various stimuli. Especially the inclusion of the HMA environment is a strength because it is understudied and reveals new, unexpected findings. Another strength is the inclusion of the Awe Experience Scale (AES) and its six facets as a measuring tool. The majority of studies used the body perception task or self-ratings to measure awe, which only gives input about one facet of awe (van Elk et al., 2016). The AES allows for a more in-depth examination of awe experiences than is possible from a broad, generalized approach.

Limitations

There are several limitations of this study. The first limitation refers to the data analysis of the study. The sample size consisted of 40 participants, whereas 60 participants were the goal to ensure a normal distribution of data and an appropriate data analysis. Possible reasons for this lack of recruited participants can be the fact that the experiment was tied to the location of the university and participants were obligated to approach which makes it impractical in comparison to online surveys for example. The smaller sample size influenced the data analysis because the data was not normally distributed which means that there was more variability and an increased sensitivity to outliers. The small sample size could have inflated effect sizes which can also be seen at the Cohens d of the facets, because there was a large effect for every facet. Another consequence was that z-scores could not be used because there were extreme values, hence only the V-score of the Wilcoxon signed-rank test was used.

Another limitation refers to the procedure of the experiment. When looking at the results of the AES before exposure to the VR environment, there are equal baseline scores for every facet except for the facet alteration in time. The pre-awe scores for alteration in time seem to be unusually high for this facet compared to all the other facets, indicating that the procedure could have influenced the perception of time before the experiment. The participants were told to be aware of the situation and perceive the current moment, which is another form of mindfulness. According to Kramer and Sharma. (2013), mindfulness is a variable influencing the perception of time, hence it could have affected the pre-awe scores and consequently the general results for this facet. This limitation could have been avoided by instructing the participants differently and giving instructions that avoid addressing the moderating variable of mindfulness.

Future Research

The study showed that all environments have a unique way of triggering awe. While there is an abundance of qualitative studies in this domain (Graziosi & Yaden, 2019; Büssing 2021), incorporating such an approach into future studies could provide additional insights. This inclusion would have allowed for a more thorough exploration of the underlying reasons for the varied influences on the different facets of awe.

Especially the HMA environment had unexpected results which are not invested enough yet. One study closer examines how certain specific architectural properties impact awe more effectively than others, for example immensity, decoration and brightness conditions (Negami & Ellard, 2021). As HMA is pervasive of our daily surroundings there is a notable gap in understanding its psychological impact on emotions, particularly in eliciting awe. This aspect warrants further exploration, considering its potential as a frequent, real-life trigger for awe experiences. (Negami & Ellard 2021).

Apart from that, the technical features of VR and its influence on awe could also be a topic of interest in the future. Especially the level of interactivity in the environments could be further investigated, as the results from this study show that there could have been some influence by this aspect. Whereas Quesnel and Riecke (2018) already hypothesized that interactivity impedes the experience of awe, Chirico and Gaggioli (2023) added that interactivity in awe studies does not have any effect to the emotion because awe has a contemplative nature. Researchers hypothesize about the effects of interactivity, nonetheless evidential results are missing in this area.

Conclusion

This study had the aim of exploring how different environments in VR influence the perception of awe and its different facets in VR. The natural environment performed best in eliciting awe, which is followed by the space and HMA condition. Inducing awe in a controlled awe setting enabled the closer examination of the effects on the different facets of awe and revealed that every environment triggered awe in a unique fashion which should be closely examined in future research.

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Appendix

Appendix A

Awe Experience scale

	Strongly disagree	Moderately Disagree	Somewhat disagree	Neutral	Somewhat agree	Moderately Agree	Strongly agree
I sensed things momentarily slow down							
I experienced a reduced sense of self							
I had chills							
I experienced a sense of oneness with all things							
I felt that I was in the presence of something grand							
I felt that my sense of self was diminished.							
I noticed time slowing							
I had the sense of being connected to everything							
I felt small compared to everything else							
I perceived vastness							
I felt challenged to understand the experience							
I felt my sense of self shrink							
I felt closely connected to humanity							
I gasped							
I felt my sense of self become somehow smaller							
I had a sense of complete connectedness							
I struggled to take in all that I was experiencing at once							
I felt my eyes widen							
I experienced something greater than myself							
I found it hard to comprehend the experience in full							
I perceived something that was much larger than me							
I felt my sense of time change							
I felt my jaw drop							

I felt challenged to mentally process what I was experiencing	○	○	○	○	○	○	○
I had the sense that moment was lasting longer than usual	○	○	○	○	○	○	○
I felt in the presence of greatness	○	○	○	○	○	○	○
I felt a sense of communion with all living things	○	○	○	○	○	○	○
I had goosebumps	○	○	○	○	○	○	○
I experienced the passage of time differently	○	○	○	○	○	○	○
I tried to understand the magnitude of what I was experiencing	○	○	○	○	○	○	○

Appendix B

Informed Consent

Informed Consent

Title of the Study: Understanding the Influence of Awe in Virtual Reality on Well-being.

Principal Investigators: Jessica Erlich, Christopher Keller

Welcome!

You are invited to participate in a research study that aims to investigate the influence of different virtual environments on the experience of awe and social well-being. Before you decide to participate, it is essential that you understand the nature of the study, the procedures involved, and the potential risks and benefits associated with your participation.

The purpose of this study is to examine how exposure to different virtual environments influences the experience of awe and social well-being. Awe is a powerful emotion which we get in the presence of something vast that challenges our understanding of the world, like looking up at millions of stars in the night sky or marveling at the birth of a child. Current research suggests that experiences of awe may relate to social well-being. We are therefore aiming to explore factors that influence how strongly awe is experienced and how different awe experiences impact social wellbeing. Your participation will involve engaging in a virtual reality (VR) experience and completing two questionnaires before and after the VR session. The whole experiment will take approximately 30 minutes to complete.

Procedures:

1. You will be asked to read and sign this informed consent form before participating in the study.
2. You will engage in a virtual reality (VR) experience designed to induce awe.
3. Before and after the VR session, you will be required to complete a questionnaire that assesses your experience of awe and social well-being.

Risks

This research has been reviewed and approved by the BMS Ethics Committee/domain Humanities & Social Sciences. Participating in this study involves minimal risks. Some individuals may experience discomfort or motion sickness during VR exposure. You have the right to withdraw the experiment at any time if you feel uncomfortable without negative consequences or the duty of providing reasons.

Benefits

The potential benefits of this study include contributing to the understanding of how different virtual environments influence the experience of awe and social well-being, which may have implications for future research and the development of VR applications. The experience of awe also induces positive benefits for your well being according to research.

Confidentiality:

Your participation in this study is confidential. Your personal information will be anonymized and kept confidential. Only the principal investigators and supervisor team will have access to the data. It will be stored on password protected Computers and deleted after it has been analyzed for the sake of answering the Research questions.

Contact Information:

If you have any questions about the study or your participation, please contact:

Jessica Erlich j.erlich@student.utwente.nl +4917658862059

Christopher Keller c.keller@studetn.utwente.nl +491715714919

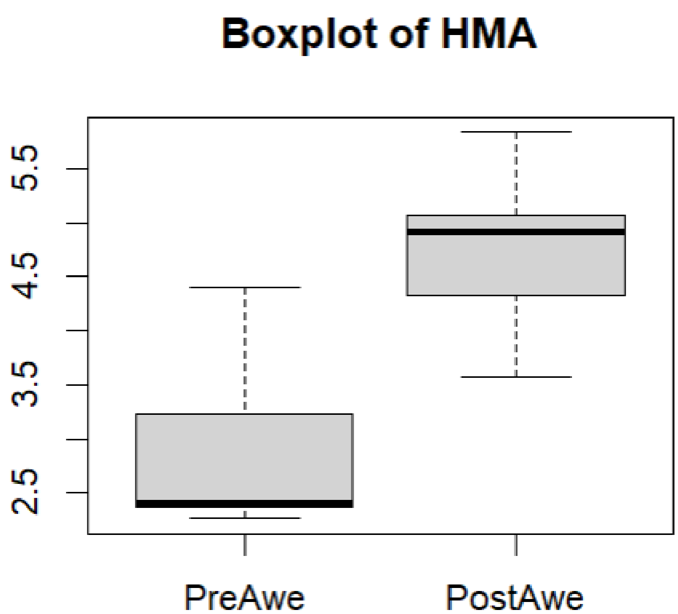
For more specific questions you can also contact the supervisors of this study:

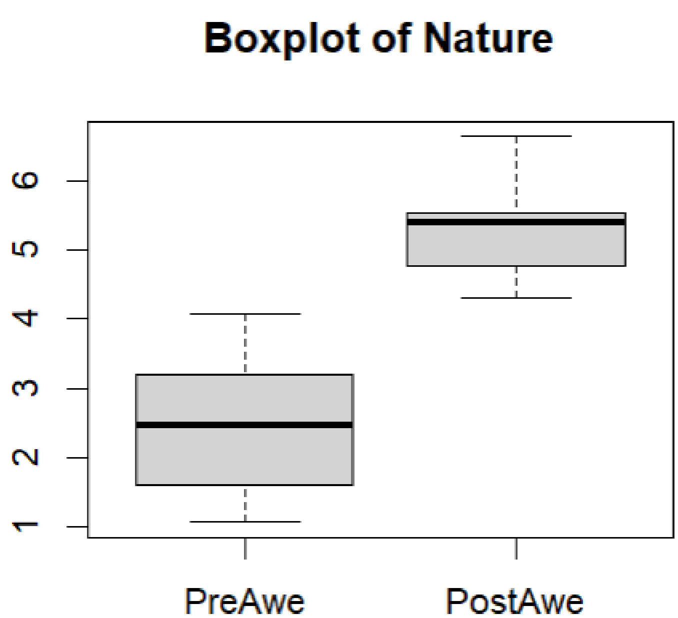
Lina Bareisyte l.b.bareisyte@utwente.nl

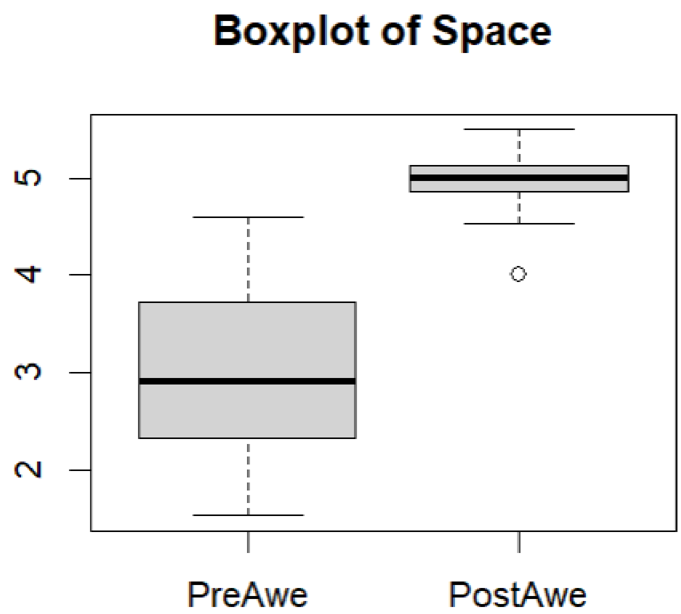
Anneke Sools a.m.sools@utwente.nl

Appendix C

Boxplots for Normality Check






Boxplot of Space
5
4
3
2
PreAwe
PostAwe